ROSEDALE-RIO BRAVO
WATER STORAGE DISTRICT

GROUNDWATER MANAGEMENT PLAN

INDEX

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INTRODUCTION

The Rosedale-Rio Bravo Water Storage District (District) is located in Kern County on the extreme westerly edge of the City of Bakersfield. Approximately 70% of the Districts gross acreage of 43,000 acres is devoted to irrigated agriculture.

The District was formed in 1959 for the purpose of constructing and operating a groundwater recharge project. Prior to construction of the Isabella Dam by the Corps of Engineers in 1954, the Kern River would overflow into what was known as the Goose Lake Slough and would recharge the groundwater basin. When these overflows ceased, groundwater levels began to drop by 8 to 10 feet per year.

Subsequent to the formation of the District, a water supply contract was negotiated and entered into with the owners of interest in the waters of the Kern River. Today this owner of interest is the City of Bakersfield. The contract calls for an annual block of basic contract water of 10,000 A.F. and a one third interest in what is commonly called miscellaneous water.

In 1966 the District entered into a water supply contract with the Kern County Water Agency to obtain an entitlement of imported State Water Project Water from the California Aqueduct at Tupman with a maximum firm water entitlement in the amount of 29,900 A.F. annually. There are also times when water is available to the District from the Federal Friant Kern system by exchange, or as a result of excess flows or what is called 215 water. The right-of-ways along the slough and the adjacent ponds today comprise some 750 acres of which 470 acres can be used for direct recharge. The District's recharge facilities consist of recharge basins, improved unlined channels and natural channels. The facilities generally follow the alignment of the Goose Lake Slough.

The total amount of water deliveries to the District's facilities up to the present time is nearly 2,000,000 A.F. The Rosedale-Rio Bravo Water Storage District has been proactive since its inception in utilizing all reasonable means to balance the groundwater basin. The goal of the District is to balance recharge with consumptive use while respecting adjacent landowners and other basin users.

In its continuing efforts to achieve this goal the District has authorized the development of a draft Groundwater Management Plan under AB3030. This plan will identify and quantify the surface and groundwater supplies available to the District and define the interaction between these supplies and the water demands of the District both now and in the future.

Much of the information covered in this plan is currently collected by the District and analyzed on a regular basis. However, the intent of this plan is to provide a focus for future enhancement of the District's project.

PLAN OBJECTIVE

The District desires to formalize its groundwater management practices to provide for the continuance of local management and to enhance existing monitoring activities. Through this Plan, the District will identify and implement modifications to ongoing practices in order to preserve and enhance groundwater resources. The District will organize existing and expanded groundwater management activities under provisions of Part 2.75 (commencing with Section 10750) of Division 6 of the California Water Code, otherwise known as the Groundwater Management Act of 1992 (AB 3030).

MANAGEMENT AREA

The District's management area will initially have the same boundaries as the District. However, the groundwater basin underlying the District is part of the Kern County portion of the San Joaquin Valley Groundwater Basin. Thus the groundwater underlying the District is influenced by the uses of surface water and groundwater in the areas surrounding the District. For this reason, it is anticipated that the District might ultimately be a part of a larger multi-district management plan.

SURFACE WATER SUPPLY

Groundwater management in the District is based on the conjunctive use of surface and groundwater resources and has been practiced since early in this century when, on average, the Kern River would overflow every three years thus filling the Goose Lake Slough and recharging the groundwater basin.

Water supplies received from the Kern River by contract with the City of Bakersfield, an entitlement of 29,900 A.F. by contract with the Kern County Water Agency for State Water Project water and sporadic quantities of water from the Central Valley Projects Friant System comprise the overall supplies the District manages for optimum use.

Under this Plan, the District will seek to preserve the existing water contracts as well as pursuing all reasonable opportunities to supplement these supplies through importation of additional water and the feasibility of reclaimed or conserved supplies.

GROUNDWATER BASIN CHARACTERISTICS

The physical characteristics of the groundwater basin influence the content of the Plan. In particular, the manner in which groundwater is replenished is directly affected by surface and subsurface characteristics, such as the permeability of the overlying and subsurface soils. The District overlies areas of both unconfined, and semi-confined aquifers.

PLAN ELEMENTS

GROUNDWATER RECHARGE

The replenishment of the underlying groundwater occurs naturally by subsurface migration, but principally through deliberate, controlled means. The District's groundwater replenishment is achieved by controlled means through direct recharge to the underground and through the delivery of surface water, when available, to lands otherwise relying on the groundwater resource.

Direct recharge is achieved through the placement of surface water in channels or basins located on permeable soils for the express purpose of percolation to the underground. The District's facilities substantially consist of unlined channels and ponds. As a result, approximately 80-90 percent of the surface water supplies diverted into the District's facilities percolates to the groundwater basin in the form of direct recharge. The District also has recharge areas it has been able to use through the cooperation of the landowners during extremely wet years. It is the intention of the District to develop additional groundwater recharge capability. The District is a participant in the KCWA sponsored Pioneer Project which will provide the District the opportunity to recharge high flow water supplies on the Kern River Fan within a few miles and up-gradient of the District's southern boundary. The District is also investigating the purchase of recharge property adjacent to its existing facilities, including land currently owned by the KCWA.

Delivery of surface water for irrigation reduces the need for water users to draw on groundwater thereby conserving the water available in the aquifer for later use. The use of surface water in this manner is known as in-lieu recharge. Landowners adjacent to project facilities are encouraged to take delivery of such surface supplies. An additional benefit is derived when irrigation water applied beyond crop water needs percolates to the underground.

Importation of affordable water supplies, in quantities sufficient to achieve a long term water balance within the District is a prerequisite for successful implementation of the recharge programs described here. All opportunities to supplement the regular supplies of the District through water exchange and banking agreements with outside entities will be evaluated for compatibility with the goals of this Plan.

Effective groundwater replenishment involves the management of water supplies available to the basin and extractions from the basin. Extractions within the management area are primarily by private wells. The District will continue pricing surface water at rates which encourage water users to use surface water in-lieu of pumping groundwater where possible. Further management of groundwater extractions may need to be evaluated in the future.

CONJUNCTIVE USE OF SURFACE AND GROUNDWATER

As previously stated, groundwater management is the conjunctive use of surface water and groundwater supplies where conjunctive use refers to integrating the two sources of supply to achieve the optimal use of each. In years of abundant supply, surface water is stored in available aquifers. In years of shortage, that previously stored water is pumped to supplement available surface water. The District will attempt to maximize the utilization of available facilities and resources for conjunctive use through cooperative management.

Conjunctive use opportunities motivated the District to enter into the water supply contract with the KCWA for imported water from the SWP. Water transfers and exchanges are an integral part of the District's existing conjunctive use programs. Under the Plan, the District will seek to preserve and enhance conjunctive use activities through coordinated use of available supplies made possible by water transfers and exchanges and through expansion of recharge facilities. Enhancement of conjunctive use activities could include the development of water banking arrangements with other agencies by utilizing available groundwater storage capacity for the temporary storage of water.

MONITORING

Optimal use of the groundwater resource is dependent on the acquisition of good basic data respecting both geology and hydrology. The purpose of this element of the Plan is to monitor conditions within the groundwater basin to identify changing conditions which may require attention. Monitoring includes gathering and analyzing basic data to characterize the basin which provides the information necessary for future management decisions. Present activities in this regard may be enhanced to provide a more complete picture of the condition of the groundwater resource.

Groundwater Levels

Data on groundwater levels are used to evaluate groundwater movement and storage conditions. Groundwater contour maps showing lines of equal elevation of the water surface indicate the direction of groundwater movement and also can be used to develop estimates of groundwater flow entering or leaving the management area. Maps of depth to groundwater can provide insight into the distribution of pumping lifts and resultant energy cost for extraction. Maps showing changes in groundwater levels, when used in conjunction with data on specific yield, can also be used to estimate changes in groundwater storage.

The District routinely measures groundwater levels in 23 agricultural water wells and 4 dual-completion monitor wells constructed by the DWR. These measurements are made monthly. The present monitoring networks will be maintained or enhanced to assure the availability of sufficient data for the preparation of groundwater contour maps. Measurement of groundwater levels will continue to be performed monthly to demonstrate annual variation.

Groundwater Quality

Monitoring of groundwater quality provides the information required for determination of the suitability of groundwater for various uses. Currently, groundwater quality monitoring is conducted by the retail water purveyors in the District. The sampling of additional wells may be necessary to provide sufficient data to allow identification of water quality problem areas. Supplemental sampling may also be performed to better define localized areas of impaired water quality. Testing will typically include standard agricultural type analysis, but may also include additional testing (e.g. Title 22) as required.

Well Construction Abandonment

The increase in groundwater extraction resulting from the construction of additional wells affects the long-term water balance of the region. Well construction or abandonment may allow contamination of the groundwater if not done properly. Both construction and abandonment must be conducted in conformance with standards adopted by the County of Kern. The District will monitor these activities by reviewing records compiled by the County. Appropriate information on proper construction and abandonment will be made available through the District.

Water Supply and Water Use

Data related to the hydrologic inventory will be collected annually for quantification and analysis. Components of the inventory include precipitation, evaporation, cropping pattern, and all surface water supplies.

Annual Report

Documentation in the form of an annual report will be prepared as required to document the results of the monitoring elements of the Plan. The contents of the report may include:

1. Maps and/or tables showing:

   a) Spring and fall groundwater elevations

   b) Spring and fall depths to groundwater.

   c) Change in groundwater levels between subsequent spring readings.

   d) Groundwater quality.

2. Estimation of the change in groundwater storage computed using specific yield data and maps of change in groundwater levels.

3. Summary of water resource data.

4. Estimation of long term water balance.

5. Assessment of the effectiveness of management activities.

INSTITUTIONAL CONSIDERATIONS

California Water Code, Sections 10750, et seq., provide the District with the powers to adopt and implement a Plan. Powers granted to an entity which adopts a Plan include the powers of a Water Storage District pursuant to Part 4 (commencing with Section 60220) of Division 18 of the California Water Code to the extent not already possessed by the District including but not limited to the following:

1. Acquire and operate facilities, waters and rights needed to replenish the groundwater supplies.

2. Store water in groundwater basins, acquire water rights, import water into the District and conserve water.

3. Participate in legal proceedings as required to protect and defend water rights and water supplies and to prevent unlawful exportation of water from the District.

4. Under certain conditions, to exercise the right of eminent domain.

5. Act jointly with other entities in order to economically perform required activities.

6. Carry out investigations required to implement the Plan.

7. Fix assessment rates for water for replenishment purposes.

8. Fix the terms and conditions of contracts for use of surface water in-lieu of groundwater.

9. Fix and collect fees and assessments for groundwater management in accordance with Part 6 (commencing with Section 60300) of Division 18 of the California Water Code.

ASSESSMENTS

Upon adoption of this Plan, the District will continue to levy and collect water toll charges through the County tax bills as well as surface water charges based on the amount of water taken from the channel. Any assessments or fees proposed to be collected by the District under this Plan may, under certain circumstances, require an area-wide election before implementation.

MANAGED CONJUNCTIVE USE OF GROUNDWATER STORAGE

Monique Roberts[1] and Harold Crossley[2]

ABSTRACT: The Rosedale-Rio Bravo Water Storage District (District) developed a groundwater recharge project in 1960 to capture available surface waters and provide a conjunctive use water supply to a 43,000 acre agricultural area in Kern County, California. Since that time, urban encroachment has resulted in the conversion of over 6,000 acres to residential, commercial and industrial use. The project facilities generally follow the alignment of an historic Kern River overflow slough, utilizing the natural recharge capabilities of those soils. The District currently has contracts for water supply from the State Water Project and the Kern River, and has taken delivery of surplus federal water when available. The water supply from these sources varies greatly, both seasonally and from year to year, depending on runoff conditions. Therefore, the project was designed to manage these variable water supplies through conjunctive use of the groundwater basin. Water is recharged and stored in the underlying groundwater aquifer in times of surplus and then pumped for use by both farmers and urban users as needed. The project now has a diversion capacity of 400 cfs and the capability to recharge in excess of 150,000 acre-feet per year.
KEY TERMS: artificial groundwater recharge; conjunctive use; groundwater hydrology; water management

INTRODUCTION

The Rosedale-Rio Bravo Water Storage District (District) is located west of Bakersfield, California, and contains approximately 43,000 acres of predominantly agricultural land. The District was formed in 1959 for the purpose of constructing and operating a groundwater recharge project to offset declining groundwater levels. Historically, the Kern River would overflow into the Goose Lake Slough channel, which traverses the District, an average of once every three years. Groundwater levels in the area would increase significantly after such overflows. The Isabella Dam, constructed by the Corps of Engineers in 1954, substantially reduced the probability for these overflows. This, in combination with increased agricultural development within and surrounding the District, resulted in a rate of groundwater decline of about eight to ten feet per year in 1959 (State of California DWR, 1959).

The location of the District is shown in Figure 1. The project facilities generally follow the alignment of the Goose Lake Slough, utilizing the natural recharge capabilities of those soils. Water supply contracts provide for delivery of water to the project from the adjacent Kern River and nearby state and federal water facilities. The water supply available to the District varies greatly, both seasonally and from year to year, depending on runoff conditions. The groundwater aquifer functions as a storage reservoir that provides both seasonal and long-term regulation of variable water deliveries to meet demands. Urban encroachment has resulted in the conversion of over 6,000 acres to residential, commercial and industrial use. The project now has a diversion capacity of 400 cfs and the capability to recharge in excess of 150,000 acre-feet per year.

This paper evaluates records of the District's 35 years of operation to determine the impact of the conjunctive use project on groundwater conditions. The economic performance is addressed, and the relationship between actual and theoretical recharge percolation rates vs. time is compared.

PROJECT HISTORY AND FACILITIES

Table 1 lists significant events in the history of the project. Project facilities (Figure 1) extend along approximately 15 miles and have been improved and expanded in the years since construction of the original project. As of January 1997,

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the District's recharge and transportation facilities covered approximately 730 acres. The net area available for surface water spreading totaled about 568 acres. Water for agricultural and urban uses is supplied by privately owned wells located throughout the District.

TABLE 1. Recharge Project History

Date	Activity
1959	District organized.
1961	Original project constructed. CVP and KR deliveries start.
1976	CVC constructed. SWP deliveries start.
1996	Cumulative deliveries of 2.0 million acre-ft.

Notes: CVP = Central Valley Project (Federal), KR = Kern River,
SWP = State Water Project, CVC = Cross Valley Canal.

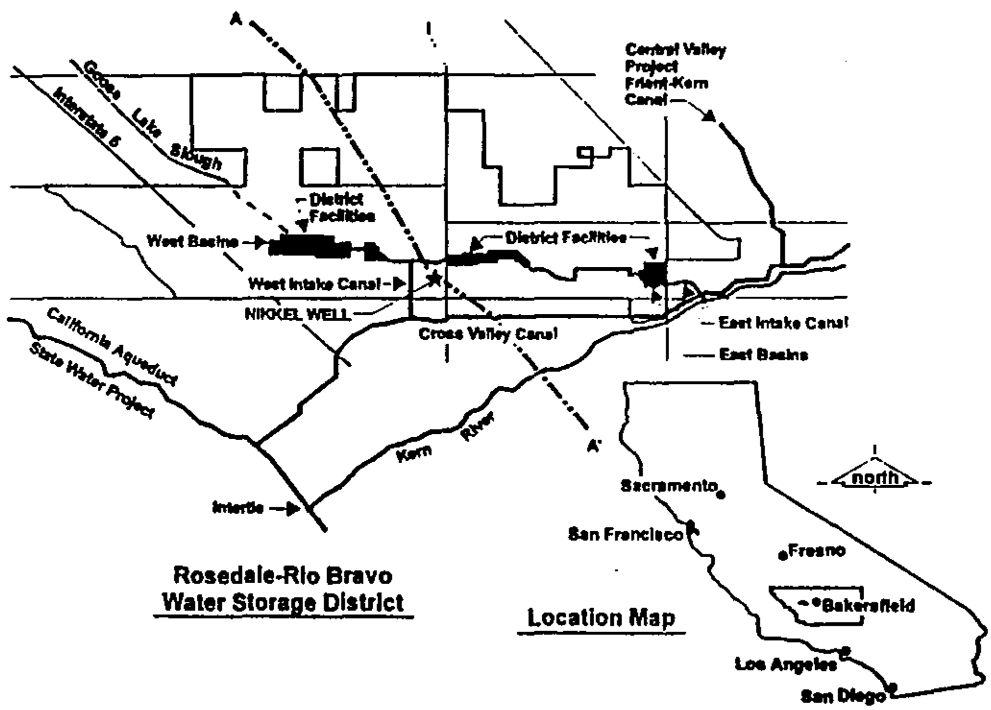

FIGURE 1. Location Map

PROJECT OPERATION

If adequate aquifer storage capacity is available, the amount of water that can be recharged is contingent upon the size of the net (wetted) recharge area and the infiltration rate. Infiltration rates vary over time and throughout the project depending on soil permeability, flow rates through recharge areas, water supply silt loading and water temperature. Table 2 summarizes the average infiltration rates for the District as determined from operating experience.

TABLE 2. District Groundwater Recharge Project Infiltration Rates

	Recharge Area (acres)	Average Infiltration Rates (ft/day)
East Basins	118	1.1
West Basins	224	0.4
Channels	226	0.8
TOTAL	568	0.7[1]

Notes:
1. Project weighted average infiltration rate based on net recharge.

Applying the 0.7 ft/day average infiltration rate to the 568 acres of spreading area, the average recharge capacity is estimated to be 145,000 acre-ft/yr, or about 200 cfs. The peak infiltration rates that occur on start-up are much greater, with the peak capacity of the project close to 400 cfs. Steady state conditions are reached after about 120 days of in-flow to recharge facilities. Horton (1940) developed an equation defining the relationship between infiltration rate and time. Figure 2 shows an infiltration rate vs. time curve for project facilities developed using Horton's equation and field measurements (Maddock, 1982).

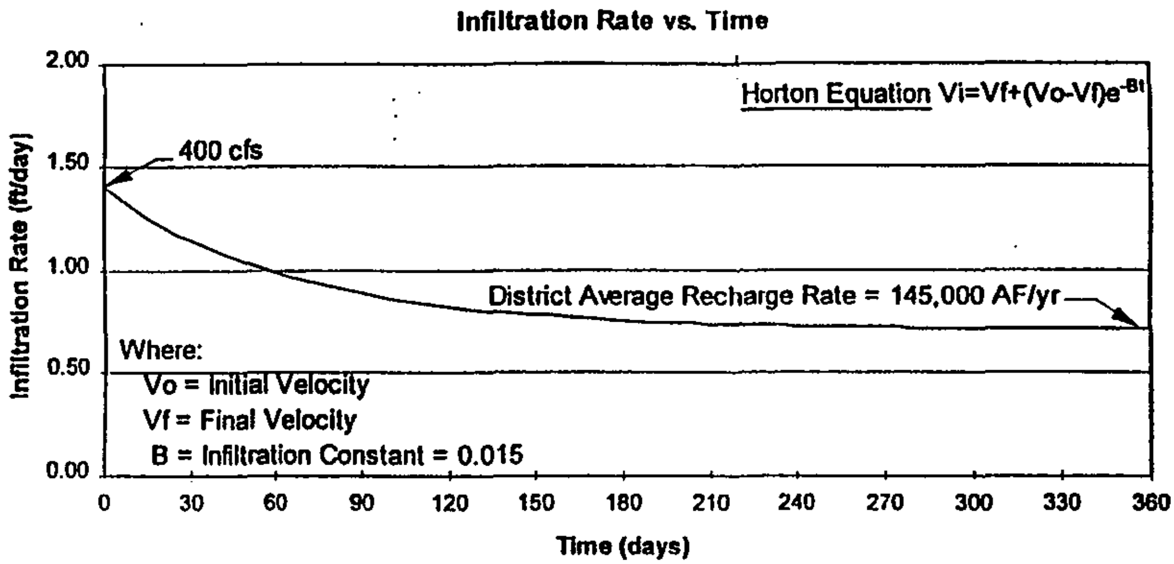

FIGURE 2. Infiltration Rate vs. Time

The District also makes surface deliveries to agricultural landowners located adjacent to project facilities when water is available. These deliveries in-lieu of groundwater pumping are additional form of groundwater recharge. Surface deliveries to landowners have averaged about 10,000 acre-ft/yr since 1976. This results in an average annual recharge capacity of 155,000 acre-ft/yr.

The total developed area within the District has increased from 25,000 acres in 1961 to 34,500 acres in 1996. In 1961, generally all development in the District was for agricultural purposes. Due to urban encroachment, about 6,000 acres were devoted to residential, commercial or industrial use in 1996. The extent of urbanization is also illustrated by the increase in parcels. In 1959 there were about 700 parcels in the District. By 1996 the number of parcels had increased to over 5,600 with 4,700 of those less than 5 acres in size.

The irrigated area is predominantly cotton (44%), alfalfa (22%), deciduous trees (12%), grains (11%), and vegetables (9%). Consumptive use is estimated to have increased from 62,500 acre-ft/yr in 1961 to 82,000 acre-ft/yr in 1996. Applied water requirements are estimated to have increased from 85,000 acre-ft/yr in 1961 to 110,000 acre-ft/yr in 1996. The history of the developed acreage and water use in the District, both consumptive and applied, is summarized in Table 3.

TABLE 3. RRBWSD Irrigated Acreage and Water Use

Year	Gross Developed Acres (1000 Acres)			Water Use[1] (1000 acre-ft)	
	Ag	Urban	Total	Consumptive[2]	Applied[3]
1961	25.0	0	25.5	62.5	85.0
1971	27.7	0	27.7	70.5	93.2
1981	34.7	2.7	37.4	92.1	123.7
1996	28.9	5.6	34.5	82.0	110.3

Notes:

1. Urban use estimated based on average water use information from mutual water company representatives
2. Agricultural consumptive use values based on DWR Bulletin 113-3 (State of California DWR, 1974).
3. Applied water requirements for agricultural use based on average irrigation efficiency of 75%.

Table 4 provides information on the District's water supply contracts and water deliveries. Figure 3 is a hydrograph depicting water deliveries by source for each of the 35 years of project operation. Figure 4 illustrates deliveries on a monthly basis for 1995 (a wet year).

TABLE 4. District Water Supply Contracts

Source	Contract Quantity (1000 acre-ft/yr)		1996 Unit Cost[1] ($/acre-ft)		Water Deliveries 1962-96 (1000 acre-ft)	
	Firm	Surplus	Firm	Surplus	Total	Average/yr
KR	10	As Available	2.8	12.05	1110	31.7
CVP	0	As Available	NA	10.00	289	8.3
SWP	30	As Available	45.80	22.30	605	17.3[2]
TOTAL					2004	57.3[3]

Notes:
1. Unit costs include transportation to District intake facilities.
2. SWP deliveries started in 1976 and have averaged about 28,000 acre-ft/yr since then.
3. Annual average deliveries from 1976-96 (after the SWP) are 66,300 acre-ft/yr.

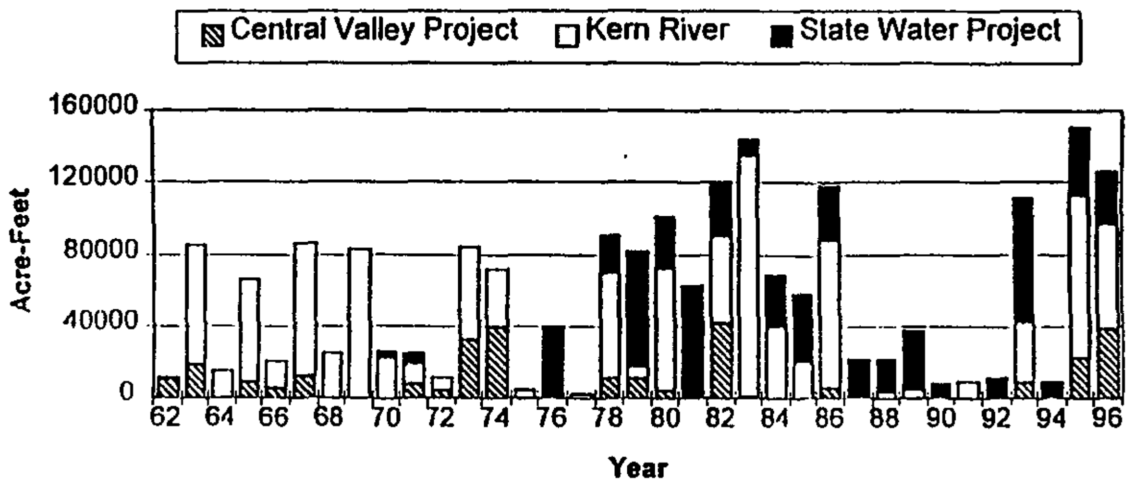

FIGURE 3. Water Deliveries to District

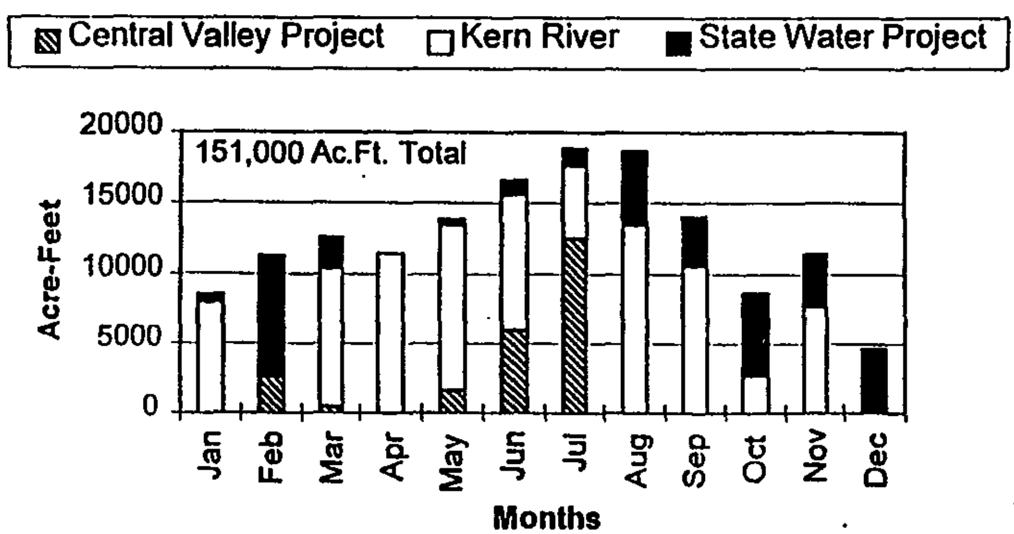

FIGURE 4. Monthly Deliveries for 1995 (Wet Year)

From 1962 through 1996, a total of 2,004,000 acre-ft have been delivered to the project. Assuming losses due to evaporation and evapotranspiration at 6% of deliveries, about 1,884,000 acre-ft (53,800 acre-ft/yr), or about 69% of the cumulative consumptive use, has been effectively recharged to the groundwater basin. This suggests that the average rate of groundwater decline of 9.1 ft/yr without the project should have been reduced to about 2.8 ft/yr, neglecting influences of subsurface inflow and outflow. The direction of groundwater flow is primarily to the northwest, away from the Kern River channel.

As determined from groundwater measurements at monitoring wells located throughout the District, the actual rate of decline has been reduced to 2.0 ft/yr. This is about 22% of the estimated rate at which groundwater levels would have declined without the project. It is estimated that groundwater levels are now an average of about 240 feet higher than might have prevailed without the project. This beneficial impact takes into consideration the increase in consumptive use since 1962. Figure 5 shows the District-wide average elevation of groundwater for the period 1955-1996.

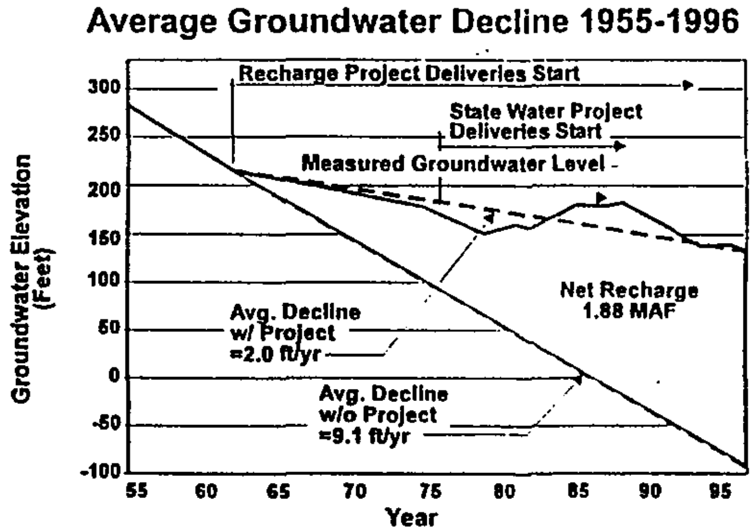

FIGURE 5. Average Groundwater Elevation 1955-1996

Drought conditions during the periods from 1976-77 and 1987-92 resulted in significantly reduced water deliveries. Figure 6 shows groundwater cross-sections through the District over time. Figure 7 shows groundwater levels at the Nikkel monitoring well and water deliveries from 1974 through 1996, which includes both wet and dry conditions. See Figure 1 for the cross-section and well locations. As expected, the groundwater level rises in response to recharge during wet years and declines during drought conditions. The groundwater basin functions similar to a surface water reservoir.

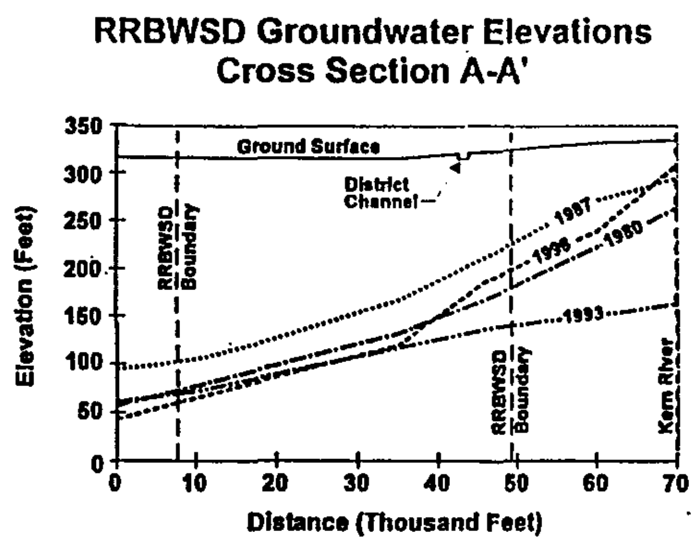

FIGURE 6. Groundwater Cross Section

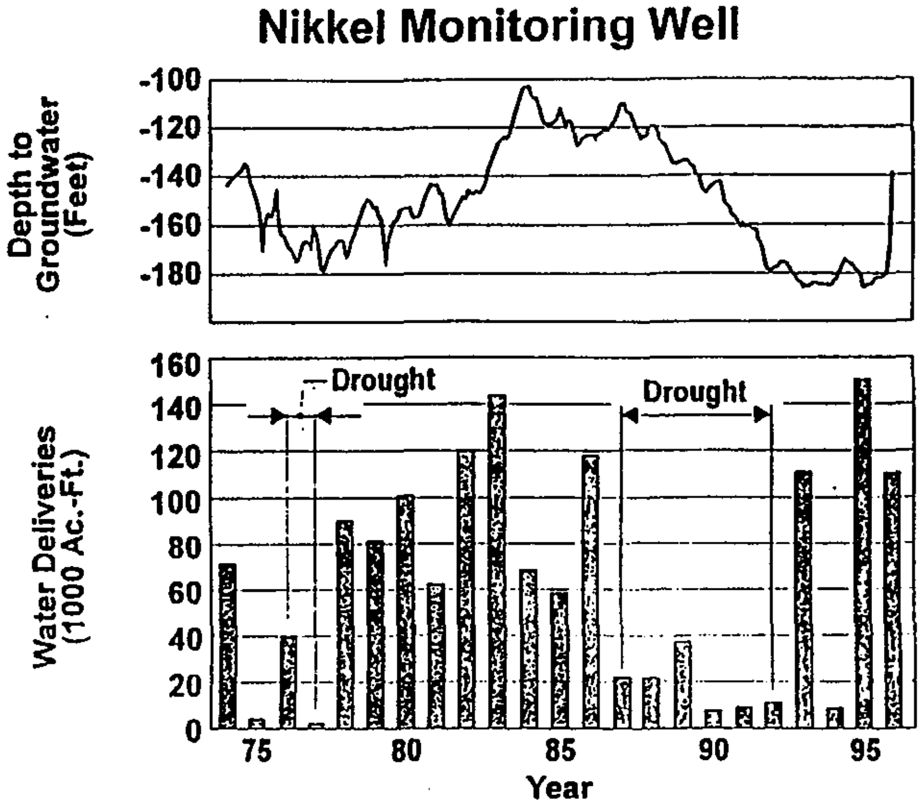

FIGURE 7. Long Term Groundwater Levels

The recharge of additional water supplies has also had a beneficial impact on groundwater quality conditions in the District. The groundwater underlying the District is generally of good quality, especially for agricultural use. However, there are areas within the District that were found to have groundwater contaminated with nitrate, salts, EDB and DBCP, particularly the groundwater at a depth of 500 feet or less. The source of this contamination is believed to be the historical industrial and agricultural activities in the area (Longley, 1990). Recharging good quality water has been found to maintain or improve groundwater quality. The results of groundwater testing by the Vaughn Water Company and other domestic water suppliers in the District show a decrease in contaminants after periods of recharge (Vaughn, 1996).

ECONOMIC EVALUATION

The District's facilities, water supply and operations have all been paid for by the landowners within the District. The District landowners, both irrigation and urban well pumpers, also benefit from the project because of higher groundwater levels. Long term savings accrue through reduced pumping energy costs and reduced capital expenditures for well and pump modifications that would have been required for lower groundwater levels. The mutual water companies providing service to the 6,000 acre urbanized area currently use groundwater as their source of potable water supply. The increase in groundwater levels due to the project therefore benefits the urban area as well as the agricultural pumpers.

A comparison of costs and benefits for the District's project is presented in Table 5. The present worth of project costs including capital improvements, water purchases, maintenance, operation and administration is estimated to be $88 million based on an interest rate of 7%. The present worth of benefits due to reduced energy costs and well and pump expenditures is estimated to be $131 million, also based on an interest rate of 7%. The energy cost benefit includes future energy savings due to past operations, through the year 2010, since the groundwater levels in the District will always be higher than they would have been without project operations. This results in a favorable benefit to cost ratio of 1.6 for the project. Other benefits from the project that cannot be readily quantified are the profit realized from crops grown with a reliable groundwater supply as compared to the reduced profit and crop acreage caused by water shortages and increased pumping costs.

TABLE 5. Comparison of Costs and Benefits for RRBWSD Groundwater Recharge Project

	Present Worth[1] of Costs and Benefits ($1,000)
Costs	
Capital Cost - Improvements	22,820
Water Supply	47,095
Maintenance & Operation (Includes administration)	18,233
TOTAL COSTS	88,148
Benefits	
Energy Savings	131,400
Capital Cost - Wells	8,600
TOTAL BENEFITS	140,000

Notes:

1. Present worth as of January 1997. Calculations based on 7% interest rate.

The unit cost of water recharged to the underlying aquifer is estimated to be $44/acre-ft. The total cost of water pumped to the surface is estimated to be about $75/acre-ft ($44/acre-ft recharge cost plus $31/acre-ft pumping energy cost).

CONCLUSIONS

The District's recharge facilities allow for cost-effective management of erratic water supplies for the benefit of its landowners, whether they pump groundwater for irrigation or urban use. The ability to accept large quantities of surplus water supplies should continue to be an important method of groundwater management in the future. The continued economic performance of the project, and particularly the impact on farming, will depend on the availability and cost of water to the District.

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